



**University of
Zurich**^{UZH}

**Zurich Open Repository and
Archive**

University of Zurich
University Library
Strickhofstrasse 39
CH-8057 Zurich
www.zora.uzh.ch

Year: 2018

A virtual reality experiment for improving the navigational recall: What can we learn from eye movements of high- and low-performing individuals?

Lokka, Ismini-Eleni ; Cöltekin, Arzu

Abstract: In its broader scope, this paper is concerned about understanding how (visualization) designs of virtual environments (VE) interact with navigational memory. We optimized the design of a VE for route learning following specific visualization guidelines that we derived from previous literature, and tested it with a typical navigational recall task with 42 participants. Recall accuracies of our participants widely vary. We hypothesize that by analyzing the eye movements of high- and low-performing participants in a comparative manner, we can better understand this variability, and identify if these two groups rely on different visual strategies. Such efforts inform the visualization designs, and in turn, these designs can better assist people. Those who perform poorly in navigational tasks for reasons such as lack of training or differences in visuospatial abilities might especially benefit from such assistance. In this paper, we present our concept for a work-in-progress study and provide the relevant background.

DOI: <https://doi.org/10.3929/ethz-b-000222473>

Posted at the Zurich Open Repository and Archive, University of Zurich

ZORA URL: <https://doi.org/10.5167/uzh-165397>

Conference or Workshop Item

Published Version

Originally published at:

Lokka, Ismini-Eleni; Cöltekin, Arzu (2018). A virtual reality experiment for improving the navigational recall: What can we learn from eye movements of high- and low-performing individuals? In: 3rd International Workshop on Eye Tracking for Spatial Research, Zürich, 14 January 2018. ETH Zurich, 28-33.

DOI: <https://doi.org/10.3929/ethz-b-000222473>



Conference Paper

A virtual reality experiment for improving the navigational recall: What can we learn from eye movements of high- and low-performing individuals?

Author(s):

Lokka, Ismini E.; Çöltekin, Arzu

Publication Date:

2018-01-14

Permanent Link:

<https://doi.org/10.3929/ethz-b-000222473> →

Rights / License:

[Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International](#) →

This page was generated automatically upon download from the [ETH Zurich Research Collection](#). For more information please consult the [Terms of use](#).

A virtual reality experiment for improving the navigational recall: What can we learn from eye movements of high- and low-performing individuals?

Ismini E. Lokka, Arzu Çöltekin

Department of Geography, University of Zurich – (ismini-eleni.lokka, arzu.coltekin)@geo.uzh.ch

Abstract. In its broader scope, this paper is concerned about understanding how (visualization) designs of virtual environments (VE) interact with navigational memory. We optimized the design of a VE for route learning following specific visualization guidelines that we derived from previous literature, and tested it with a typical navigational recall task with 42 participants. Recall accuracies of our participants widely vary. We hypothesize that by analyzing the eye movements of high- and low-performing participants in a comparative manner, we can better understand this variability, and identify if these two groups rely on different visual strategies. Such efforts inform the visualization designs, and in turn, these designs can better assist people. Those who perform poorly in navigational tasks for reasons such as lack of training or differences in visuospatial abilities might especially benefit from such assistance. In this paper, we present our concept for a *work-in-progress* study and provide the relevant background.

Keywords. navigation, virtual environments, visual strategies

1. Introduction

Navigation has long been of interest to diverse scientific communities. Whether it is from a psychological perspective (e.g., tackling cognitive aspects of how people navigate), or from a more applied perspective (e.g., developing and testing tools to help people navigate); such scientific efforts are geared towards understanding and improving people's navigation experience. Improving the navigation experience is beneficial to many people considering the difficulty of navigation. Even though it might appear effort-

less in some situations, there are occasions in which people experience fear and stress while trying to find their way. In a navigation context, one needs to absorb, process, and remember a large amount of information, which might lead to what is known as ‘cognitive overload’ (Sweller, 1988). The visual information from the world --such as the visual patterns surrounding us, and the structural spatial network-- demand cognitive resources, and with increasing information, the navigational tasks might get more difficult.

To improve the navigation experience, we believe the cognitive overload should be reduced. This can be partly done by altering the appearance of the visualizations used for route learning (e.g., maps, map-like displays, virtual environments) in a way that facilitates retaining the information relevant to learning the route of interest. Specifically, we work with VEs and hypothesize that the visual design of the VE has an impact on navigational recall (memorizing relevant features), and overall route learning.

To respond to our hypothesis, we first examine the previous work and identify optimum landmark locations (e.g., at the decision points) and visuo-spatial features (e.g., structural network) that are important in navigational situations (Richter & Winter, 2014; Röser et al., 2012). Furthermore, previous work informs on balancing the levels of realism; that is, it is documented that too much realism can impair memory performance (Çöltekin et al., 2017; Smallman & John, 2005). Applying this knowledge, we create our own VE: A fictitious urban space where the most important information (landmark locations in decision points, and structural network) are selectively highlighted with photo-textures to facilitate better recall while navigating. We deliberately suppress the less-relevant visual information by showing the rest of the scene using non-photorealistic rendering (based on shading) to make the textured features even more prominent, with the intention to facilitate an easier-to-remember route (Borkin et al., 2013; Christou & Bühlhoff, 1999; Meijer, Geudeke, & van den Broek, 2009).

We expect that our propose VE (a VE that emphasizes the relevant features for path learning at the relevant locations) we will guide viewers’ attention in a way that facilitates better recall, and eventually better route learning. This paper conceptually explores if the attention guiding properties of the proposed VE can be established through eye tracking.

2. Participants’ recall accuracies and eye tracking

2.1. Importance of individual differences

In a comprehensive controlled experiment (Lokka & Çöltekin, 2017) on the memorability of our proposed VE (“MixedVE”) compared to a non-

photorealistic rendering (“AbstractVE”) and a fully photo-realistic one (“RealisticVE”); we confirmed the Mixed VE provides benefits in route memorization to its users (*Figure 1*). Because of these earlier findings, we contend that carefully designed virtual environments are good candidates to become training devices for route learning. Furthermore, we believe that such learning could be transferred to real world tasks, based on previous navigation studies conducted in VEs (Richardson, Montello, & Hegarty, 1999).

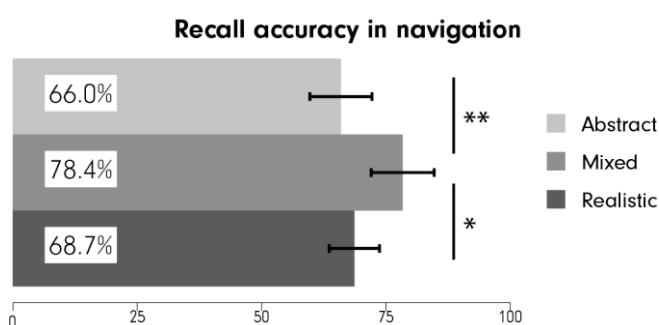


Figure 1. Participants’ recall accuracy with the three VEs. Our proposed MixedVE leads to higher success than both the Abstract and Realistic VEs. The differences are statistically significant. Error bars show \pm SEM, ** $p < .01$, * $p < .05$. (For a more detailed analysis, please see Lokka & Çöltekin, 2017).

For our proposed design (the MixedVE) to become a consistent memory-training device for route learning, we need to be sure that it assists *every-one*. This argument immediately points at the importance of individual and group differences. One way to group participants to study such differences is to group them based on their task success and analyze how and why the high-performers differ from the low-performers. If one can better understand why they differ, it may be possible to learn from the strategies of the high-performers, or compensate for the issues the low-performers face. Thus, among our 42 participants (age 20-30 y.o.), we identified the high- and low- performers in a complex recall task. After grouping them, we first study *who* are in each group. For example, we analyze if the difference is explained by their spatial abilities (as measured by the mental rotation task (MRT), (Vandenberg & Kuse, 1978)), or memory capacity (as measured by the visuospatial memory task (VSM), (Ekstrom, French, Harman, & Dermen, 1976)). Importantly, we analyze lower level cognitive processes through their eye movements; when they take the path, how do the visual scanning patterns vary between the high- and low-performers? Can we identify e.g., what important elements do the low-performing participants *not* see? If so, one can rethink the design to specifically help them.

2.2. Visual strategies of high-, and low-performers

As we examine the eye movements of these two groups, we expect to find differences in how they visually process the MixedVE. For this work-in-progress paper, we plan to examine the eye movements of the top 10 vs. bottom 10 performers, similarly as in (Çöltekin, Fabrikant, & Lacayo, 2010). We will follow previous approaches to distinguishing the ambient and focal visual search patterns (e.g., Castner & Eastman, 1984; 1985; Krejtz et al., 2017). Furthermore, we plan on and top-down and bottom-up area-of-interest (AOI) analysis to detect the two main information processing modes that would yield *global* vs. *local* visual scanning patterns (Figure 2). We expect that the local visual scanning patterns would concentrate in specific AOIs, which, we believe should be the highlighted (photo-textured) locations on the MixedVE. The global visual scanning pattern, however, would be scattered around the entire visual scene. We hypothesize that we should see more *local* visual scanning patterns with the high-performers, as the restricting the ‘learning’ to a specific and relevant part should be helpful, and the opposite behavior could suggest that the viewer is distracted. We believe one reason the low-performers ‘fail’ might be because they are not spending enough time looking at the task-relevant areas, that is, they might be scanning the scene more globally than the high-performers.

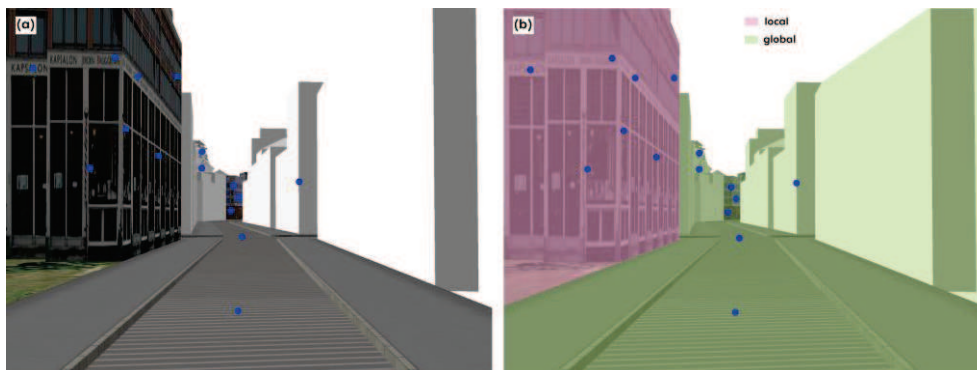


Figure 2. Example of the performed eye tracking analysis on the Mixed VE. (a) the Mixed VE environment with the photo-textured highlighted building on the left and (b) the same example with the *global* and *local* environmental grouping.

Alternatively, the low-performers might be even more focused to the highlighted areas (or even some details on the highlighted areas), which might mean they narrow the attention *too much* and do not pick up on some important cues, which the others might. At this point, we favor the first hypothesis based on the cognitive overload theory (that the high-performers should display a more localized visual search pattern than the low-

performers). The eye movement analyses are currently underway, and the results will be reported in a follow-up paper.

3. Conclusion and outlook

What are the differences between the people who have high and low recall accuracy scores in navigational tasks (such as route learning) in terms of visual behavior? This paper is a step towards linking attention to memory in the scope of our experiment. By examining the visual scanning patterns of high- and low-performing participants in a VE designed to improve the navigational recall, we might be able to deduce if the low-performers need additional consideration in specific points. Knowing where low-performers had a different strategy (or if they lack a strategy) can give us new insights in terms of possible visualization adjustments. Therefore, with a more informed design, we can offer help specifically to those who need it the most. Naturally, what might benefit the low-performers might *also* benefit the high-performers, although these remain to be tested in future studies.

References

- Borkin, M. A., Vo, A. A., Bylinskii, Z., Isola, P., Sunkavalli, S., Oliva, A., & Pfister, H. (2013). What Makes a Visualization Memorable. *IEEE Transactions on Visualization and Computer Graphics*, 19(12), 2306–2315. <https://doi.org/10.1109/TVCG.2013.234>
- Castner, H. W., & Eastman, R. J. (1985). Eye-Movement Parameters and Perceived Map Complexity—II. *The American Cartographer*, 12(1), 29–40. <https://doi.org/10.1559/152304084783914768>
- Castner, H. W., & Eastman, R. J. (1984). Eye-Movement Parameters and Perceived Map Complexity—I. *The American Cartographer*, 11(2), 107–117. <https://doi.org/10.1559/152304084783914768>
- Christou, C. G., & Bühlhoff, H. H. (1999). View Dependence in Scene Recognition after Active Learning. *Memory & Cognition*, 27(6), 996–1007. <https://doi.org/10.3758/BF03201230>
- Çöltekin, A., Fabrikant, S. I., & Lacayo, M. (2010). Exploring the Efficiency of Users' Visual Analytics Strategies Based on Sequence Analysis of Eye Movement Recordings. *International Journal of Geographical Information Science*, 24(10), 1559–1575. <https://doi.org/10.1080/13658816.2010.511718>
- Çöltekin, A., Francelet, R., Richter, K.-F., J., T., & Fabrikant, S. I. (2017). The Effect of Visual Realism, Spatial Abilities, and Competition on Performance in Map-Based Route Learning in Men. *Cartography and Geographic Information Science*, 1–15. <http://dx.doi.org/10.1080/15230406.2017.1344569>
- Ekstrom, R. B., French, J. W., Harman, H. H., & Dermen, D. (1976). Manual for Kit of Factor-Referenced Cognitive Tests. *Princeton, NJ: Educational Testing Service*.

- Krejtz, K., Duchowski, A., Coltekin, A., & Niedzielska, A. (2017). Using coefficient K to distinguish ambient/focal visual attention during map viewing. *Journal of Eye Movement Research*, 10(2), 1–13. <https://doi.org/10.16910/JEMR.10.2.3>
- Lokka, I. E., & Çöltekin, A. (2017). Toward optimizing the design of virtual environments for route learning: empirically assessing the effects of changing levels of realism on memory. *International Journal of Digital Earth*, 8947(October), 1–19. <https://doi.org/10.1080/17538947.2017.1349842>
- Meijer, F., Geudeke, B. L., & van den Broek, E. L. (2009). Navigating through Virtual Environments: Visual Realism Improves Spatial Cognition. *Cyberpsychology & Behavior*, 12(5), 517–521. <https://doi.org/https://doi.org/10.1089/cpb.2009.0053>
- Richardson, A. E., Montello, D. R., & Hegarty, M. (1999). Spatial knowledge acquisition from maps and from navigation in real and virtual environments. *Memory and Cognition*, 27(4), 741–750. <https://doi.org/10.3758/BF03211566>
- Richter, K.-F., & Winter, S. (2014). *Landmarks*. Springer Cham Heidelberg New York Dordrecht London. <https://doi.org/10.1007/978-3-319-05732-3>
- Röser, F., Hamburger, K., Krumnack, A., & Knauff, M. (2012). The Structural Salience of Landmarks: Results from an On-Line Study and a Virtual Environment Experiment. *Journal of Spatial Science*, 57(1), 37–50. <https://doi.org/10.1080/14498596.2012.686362>
- Smallman, H. S., & John, M. (2005). Naive realism: Limits of realism as a display principle. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 49(17), 1564–1568. <https://doi.org/10.1177/154193120504901714>
- Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science*, 12(1), 257–285. [https://doi.org/10.1016/0364-0213\(88\)90023-7](https://doi.org/10.1016/0364-0213(88)90023-7)
- Vandenberg, S. G., & Kuse, A. R. (1978). Mental Rotations, a Group Test of Three-Dimensional Spatial Visualization. *Perceptual and Motor Skills*, 47(2), 599–604. <https://doi.org/10.2466/pms.1978.47.2.599>